CHARACTERISTICS AND TRENDS OF AVALANCHE FATALITIES IN JAPAN (1991-2020)

Azusa Degawa[1]*

[1] *Japan Avalanche Network, Hakuba, Nagano, Japan*

ABSTRACT: There have been 179 fatal avalanche accidents in Japan over the past 30 years (1991-2020), resulting in 274 fatalities. Of the fatal accidents, 85% occur in the mountains, 6% in ski resorts, 7% at work sites such as construction sites, 1% on the roads, and 1% in facilities such as buildings. In terms of the categories of activities of the persons who died in the "mountains", "recreational activities" such as backcountry skiing accounted for 81% of the fatalities, and "industry" which comprises of various tasks performed as part of one's job, accounted for 18%. "Mountaineers" accounted for 49% of the fatalities in the category of mountain recreation, a statistic which is unique to Japan. As well, fatal accidents that occurred during job duties also include a wide variety of work-related accidents such as management of power facilities in the mountains, forestry and hunting business, and mountain guiding. Dividing the 30-year period into three 10-year segments and looking at the trends in fatalities on the mountains, we see that the number of fatalities among mountaineers is decreasing and that among skiers is increasing. Additionally, avalanche fatalities of foreign tourists visiting Japan, which were not observed before, are also occurring and it is highly likely that the percentage of fatalities among skiers will increase in the future.

KEYWORDS: avalanche accident, avalanche accident statistics, mountain recreational activities

1. INTRODUCTION

Understanding the reality of avalanche accidents is essential to consider and develop effective safety measures. In Japan, the Research Institute for Natural Hazards and Disaster Recovery (Niigata University) has compiled a Japanese Avalanche Disaster Database (Izumi, 2010) based on newspaper reports and various literature. Although the number of years covered in this database varies by region, the longest period is 144 years (1867–2010). Reports on the avalanche disasters that occurred in this period (7,940 incidents, 6,167 fatalities) are organized in a very simplified manner.

This paper was written by conducting a detailed investigation of avalanche fatalities over a 30-year period (1991–2020), referring to Dr. Izumi's database and organizing information from the Japan Avalanche Network's own accident database.

2. OVERVIEW

2.1. Number of Fatalities

In Japan, 179 fatal avalanches have occurred over the past 30 years (1991–2020), involving 574 people, injuring 139, and killing 274.

This translates to six fatal accidents and nine deaths per year. In addition, 48% of those involved in fatal avalanches died and 24% were injured. A five-year average of fluctuations in the number of fatalities shows that although there has been a downward trend in the most recent period, the number of deaths has not changed much overall (Figure 1).

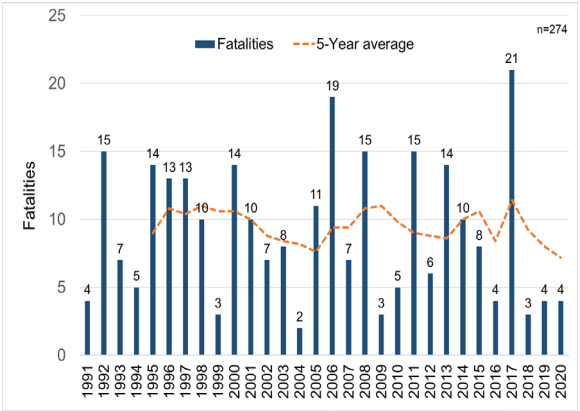

Figure 1. Avalanche fatalities from 1991 to 2020

The exact number of people engaging in activities in mountain areas, which account for 85% of the total number of fatal accidents, is not known, and as a result, changes in accident rates are unknown. Sales of avalanche protection equipment and backcountry ski equipment suggest that the

* *Corresponding author address:*
Azusa Degawa, Japan Avalanche Network,
1300-10, Hokujo, Hakuba, Nagano, Japan;
tel: +81 (0)80-2370-8041
email: degawa.azusa@gmail.com

number of backcountry skiers and snowboarders has increased in the last 15 years. However, this increase did not correlate with a higher number of fatalities.

Seasons with large increases in the number of fatalities are associated with major accidents that kill large numbers of people. There have been six seasons (2013, 2011, 2008, 2006, 2001, 2000) in which there were multiple accidents with three or more fatalities. In addition, the largest single accident in the past 30 years was the 2017 Mt. Nasu avalanche, Tochigi Prefecture, which killed eight people.

2.2. Location of Fatal Accidents

The locations of fatal avalanches, divided into five categories, are shown in Figure 2. 85% of fatal accidents occurred in "Mountain areas" and accounted for 87% of the fatalities. Mountain areas are "unmanaged areas." A location in close proximity to a ski resort is still considered a mountain area if it is outside the boundaries of the ski resort.

Accidents in mountain areas are divided into two categories: "Recreation" which includes backcountry activities, and "Industry" which includes commercial guided tours and facility management. The former accounted for 81% of fatalities, and the latter accounted for 18%.

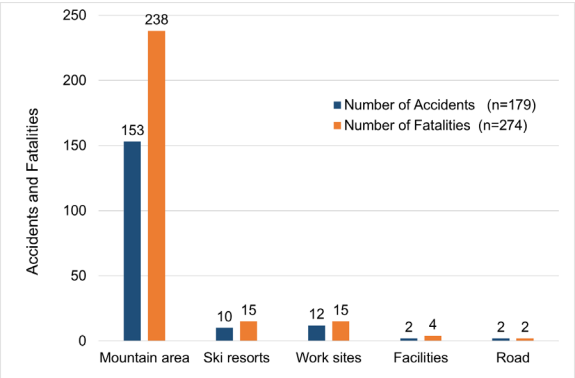

Figure 2. Location of avalanche accidents from 1991 to 2020

"Ski resort" refers to areas within the boundaries of a ski resort, which accounted for 6% of all accidents. This includes accidents that occurred in closed areas but still within the boundaries of a ski resort. There were five in-resort fatalities involving skiers, four of which were caused by skiers entering closed areas.

The one remaining case was caused by a naturally occurring avalanche of snow on the side slope of the course, which flowed into the course, and was not caused by skiing. Since this accident in 1997, there have been no avalanche fatalities on operational slopes within ski resorts.

"Work site" refers to sites where various types of construction work are being carried out, such as the installation and maintenance of rockfall and avalanche barriers on houses and roads, and disaster recovery work, and account for 7% of all accidents. In contrast, accidents involving workers that ventured deep into the mountains to manage facilities such as radio towers and dams are classified as mountain area accidents.

The two fatal accidents in the "Facility" category both occurred at hot spring facilities. In the two "Road" cases, vehicles on the road were damaged, and both fatalities were local residents.

2.3. Number of Fatalities by Prefecture

Nagano (29%), Hokkaido (16%), and Toyama (14%) prefectures account for 59% of all fatalities (Figure 3).

From a winter recreation perspective, Nagano is home to the Japanese Alps, which has many attractive mountains for both climbing and backcountry skiing, resulting in a diverse range of accidents. Toyama is home to Mt. Tsurugi (2,999 m), also known as a "temple of rock and snow," and many climbers have succumbed to its severe terrain and heavy snowfall.

Meanwhile, even in areas with heavy snowfall, the number of fatalities is low in Aomori, Akita, and Yamagata due to the overall mild terrain of the mountains and the small total number of mountain climbers.

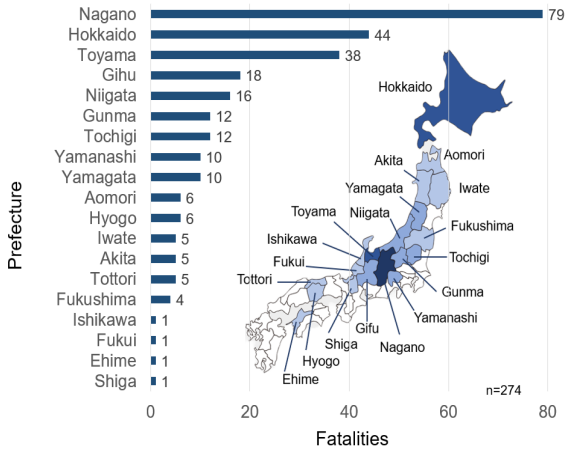

Figure 3. Fatalities by prefecture

2.4. Classification of Avalanche Fatalities

Avalanche fatalities were organized into three categories: Recreation, Industry, and Others (Table 1).

2.4.1. Recreation

Winter recreation accounted for 73.3% of all fatalities. Apart from In-area Skiers, all accidents were in "mountain areas." Details of recreational accidents in mountain areas are described in a separate section. Four accidents involving in-area skiers occurred, resulting in five fatalities. All of these accidents occurred in closed areas of ski resorts where skiing was prohibited. Of these, one case involved two people who were foreign visitors to Japan.

2.4.2. Industry

Because of the different characteristics of the activities, safety management methods, philosophies, governmental regulations, etc., these fatalities are organized by industry.

n=274

Classification	Number of fatalities (%)
Recreation	201 (73.3)
Mountaineers	96 (35.0)
Backcountry Skiers	69 (25.2)
Backcountry Snowboarders	20 (7.3)
In-area Skiers/Snowboarders	5 (1.8)
Mountain stream Fishing	6 (2.2)
Snowmobilers	5 (1.8)
Industry	67 (24.5)
Guided Tour	12 (4.4)
Ski Resort	8 (2.9)
Facility Management	18 (6.6)
Forestry and Hunting	4 (1.5)
Lodging Business	7 (2.6)
Public School Education	13 (4.7)
Public Rescue Service	5 (1.8)
Others	6 (2.2)
Residents	6 (2.2)

Table 1. Classification of avalanche fatalities

Nine fatal accidents occurred on commercial guided tours, resulting in the death of 12 people. There were two tour guide fatalities, both of whom were certified. The other ten were tour participants and included three fatalities in accidents caused by uncertified guides. When looking at the breakdown by activity, two mountaineering accidents accounted for three fatalities, one snowshoeing accident accounted for one fatality, five skiing accidents accounted for seven fatalities, and one snowboarding accident accounted for one fatality. There were two accidents involving the deaths of two foreign visitors to Japan, and both fatalities were tour participants. Of these two accidents, one was caused by an uncertified foreign ski guide.

Five accidents involving avalanche safety management at ski resorts resulted in eight fatalities. Four of these accidents were caused by ski patrol, resulting in the death of seven people. Three ski cuts failed, resulting in the death of three people, and one secondary avalanche occurred during debris removal on the slope, killing four people. The remaining fatality was a ski resort user. In this accident, a skier was killed after being caught in an avalanche that originated on the side slope of the course while skiing on a gentle course. The cause of the accident was found to be the ski resort's safety management, and the skier was not held responsible.

In the Facility Management category, 13 accidents occurred, resulting in 18 fatalities. The scope of Industry includes tasks in mountain areas, such as the management of radio towers and dam facilities, as well as at work sites, such as road snow removal, management of facilities to prevent falling rocks and avalanches, and construction for disaster recovery.

In the Forestry and Hunting category, one person was killed in an accident during the loading and unloading of harvested timber, and there was one fatality each in bear shooting and deer hunting, for a total of three fatalities.

In the Lodging Business category, two accidents occurred at hot spring facilities. In one accident, an employee was killed while clearing snow from an inn, and in the other, three guests were killed. The accident that resulted in the death of the guests occurred in a simple stone sauna facility located away from the main building. There was also one accident that resulted in the deaths of three employees of a mountain cabin.

In the Education category, four accidents occurred in public school education settings, resulting in 13 fatalities. These were all accidents that occurred during training courses. Two people died during a mountaineering course for university students at the National Mountaineering Institute, eight people died during a course for a public high school mountaineering club, and two people died during a university ski class after entering a closed area of a ski resort. The supervising University teacher as a ski instructor was charged and convicted in a criminal case.

In the Public Service category, two accidents resulted in five fatalities. One was an accident during training for a police mountain rescue team, resulting in the death of one of the team members. In the other accident, four people died in a secondary avalanche that occurred during a rescue operation. This accident, caused by a block avalanche, killed two policemen, one firefighter, and one civilian mountain rescue team member.

2.4.3. *Others*

The six cases and six people in this category are all accidents involving local residents. The victims were affected while driving a vehicle on the road or during snow removal work around their residences.

3. MOUNTAIN RECREATION FATALITIES

This category details the actual number of "Recreation" fatalities in mountain areas. The category is broken down into mountaineers, backcountry skiers or snowboarders, mountain stream anglers, and snowmobilers. Accidents in mountain areas in the "Industry" category are not included.

3.1. *Overview*

In mountain recreation, there were 131 accidents where 349 people were caught by avalanches, 52 people were injured, and 196 people were killed. Looking at fluctuations over the 30-year period in 10-year increments, there has been no significant change in the number of fatalities: 69 (1991–2000), 62 (2001–2010), and 65 (2011–2020) (Figure 4).

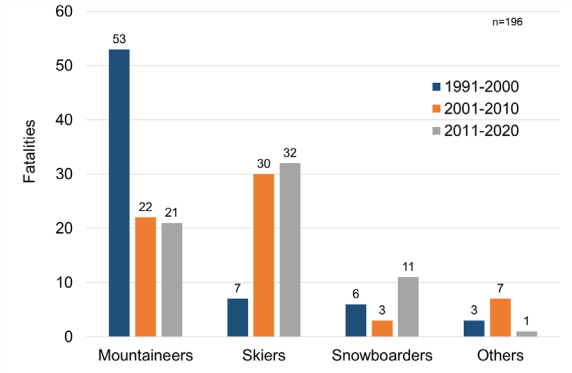

Figure 4. Change in the number of fatalities by activities

89% of fatalities were men. The age distribution is dominated by those in their 30s and 40s, which make up 50% of the total, and the average age is 42 years (median 41 years).

By activity, mountaineers accounted for 49% of all avalanche fatalities. This category includes a wide range of activities from alpine climbing to snow trekking. Since the early 2000s, the number of accidents involving backcountry skiers has increased. The other categories were accidents involving mountain stream fishing (six people) and snowmobiling (five people).

3.2. *Cause of death and burial*

Suffocation accounted for 64% of the 196 fatalities (Table 2). Trauma indicates fatal physical injury. Complete burial accounted for 58% of cases (Table 3). Even with partial burial, about half (ten people) of those affected died of suffocation. Those that cannot be determined due to insufficient information on the accident are classified as "unknown" for both cause of death and burial.

n=196

Cause of death	Number of faitalities (%)
Suffocation	126 (64)
Trauma	29 (15)
Hypothermia	8 (4)
Unknown	33 (17)

Table 2. Cause of death

n=196

Types of burial	Number of faitalities (%)
Buried	114 (58)
Partialy buried	24 (12)
Surface	7 (4)
Unknown	51 (26)

Table 3. Types of burial

3.3. *How to find buried persons*

The methods used to find victims completely buried by avalanches are outlined below (Table 4). Even if the victim is completely buried, some body parts can be seen through gaps in the debris, which can then be detected visually. Many bodies are discovered when the melting snow exposes the victim's body from the snowpack. This is mainly due to the lack of an avalanche beacon, or because the location and timing of the accident made it difficult to search immediately after the accident.

n=196

Methods of Finding Buried Persons	Number of faitalities (%)
Beacon	33 (17)
Visual	34 (17)
Probe	28 (14)
Melting snow	38 (19)
Dog	1 (1)
Other	13 (7)

Table 4. Methods of finding buried persons

3.4. Depth of burial

In mountain recreation fatalities, data is shown for 59 people in 44 cases where the depth of burial was known (Table 5). The depth of burial is the depth from the snow surface to the victim's face. The shallowest burial is 0.3 m, and the deepest is 7 m.

n=59

Depth of burial (m)	Number of faitalities (%)
0.1-0.5	14 (24)
0.6-1.0	14 (24)
1.1-1.5	15 (25)
1.6-2.0	4 (7)
2.1-2.5	5 (8)
2.6-3.0	4 (7)
3.1 over	3 (5)

Table 5. Depth of burial

3.5. Wearing avalanche beacon

Information on the avalanche beacons worn by the victims is outlined below (Table 6). Mountaineers still hesitate to carry avalanche beacons today. The spread of this practice to older skiers, who prefer more traditional tours, has also been slow. With this in mind, the unknown "U" fatalities in the table are strongly suspected to have been people who failed to carry an avalanche beacon.

n=196

	Mountaineers			Skiers			Snowboarders			Others		
	Yes	No	U	Yes	No	U	Yes	No	U	Yes	No	U
1991-2000	0	38	15	0	5	2	0	5	1	0	3	0
2001-2010	3	16	3	11	10	9	2	1	0	0	7	0
2011-2020	3	15	3	28	3	1	10	0	1	0	0	1

Table 6. Avalanche Beacons

3.6. Number of people caught in avalanches

The number of people caught in avalanches resulting in fatalities is shown below (Table 7). Although accidents involving just one person were the most common, for a total of 53, it is important to note that 19 of these accidents involved a solo traveler. Excluding accidents involving solo travelers, multiple people are swept away by avalanches in 70% of fatal accidents.

n=131

Number of people caught	Number of accidents (%)
1	53 (40)
2	33 (25)
3	18 (14)
over 4	27 (21)

Table 7. Number of people caught

3.7. Avalanche types

The types of avalanches (Statham *et al,* 2018) resulting in fatalities are shown below (Table 8). This data was only confirmed by field investigation and testimony of the parties involved. Persistent slab is mainly composed of Melt-Freeze Crust or Ice Form due to rainfall and combination of Faceted snow. There are no fatalities from surface hoar, which is common in Europe and North America. A block avalanche is an avalanche in which part of a snow cornice or snow ridge that remains in block form during the snowmelt season collapses onto a large snow mass.

n=58

Type of avalanches	Number of avalanches (%)
Storm slab	19 (33)
Wind slab	7 (12)
Persistent slab	10 (17)
Deep Persistent slab	2 (3)
Cornice	5 (9)
Dry loose	1 (2)
Wet loose	3 (5)
Wet slab	3 (5)
Glide avalanche	5 (9)
Block avalanche	3 (5)

Table 8. Type of avalanches

3.8. Avalanche size

The destructive size of avalanches (CAA 2014) resulting in fatalities is shown below (Table 9). Japanese mountains have extensive "Terrain Traps" with narrow and deep valleys, and even

relatively small avalanches of size 1.5 are the cause of many fatal accidents. Both size 3.5 avalanches were caused by naturally occurring wet slabs. In size 3, two avalanches were caused by deep persistent slabs, and three were caused by persistent slabs, all of which were triggered by skiers or snowboarders.

n=92

Avalanche size	Number of avalanches (%)
1	0 (0)
1.5	24 (26)
2	35 (38)
2.5	22 (24)
3	9 (10)
3.5	2 (2)
4	0 (0)

Table 9. Destructive size of avalanches

3.9. Elevation of starting zone

The elevation of the starting zones of fatal avalanches is shown below (Table 10). The forest line which acts as a vegetation boundary is around 1,000 m elevation in Hokkaido and around 2,500 m elevation in Nagano. However, in the winter, due to the effects of heavy snowfall, evens area at lower elevations become affected by strong winds and exhibit weather-related characteristics.

n=104

Elevation band of starting-zone (m)	Number of avalanches (%)
0-500	1 (1)
501-1000	9 (9)
1001-1500	31 (30)
1501-2000	25 (24)
2001-2500	14 (13)
2501-3000	23 (22)
3001-3500	1 (1)

Table 10. Elevation of starting zone

3.10. Aspect of starting zone

The aspect of the starting zones of fatal avalanches is shown below (Table 11). Snowfall mechanisms in Japan can be broadly divided into two categories: those associated with the passage of low-pressure systems and those caused by winter pressure patterns. In the latter, a high-pressure system is located to the west of Japan, and a low-pressure system to the east, resulting in heavy snowfall accompanied by strong westerly to northwesterly winds. Due to this pressure pattern, the northeast to southwest slopes are often downwind.

n=82

Aspect of starting-zone	Number of avalanches (%)
N	9 (11)
NE	19 (23)
E	13 (16)
SE	17 (20)
S	8 (10)
SW	3 (4)
W	5 (6)
NW	8 (10)

Table 11. Aspect of starting zone

4. DISCUSSION

In the classification of the locations of fatal accidents, the European concept of “off-piste” does not exist in Japanese ski resorts. In Japan, the national safety standard established by the ski resort industry stipulates that off-piste skiing is prohibited. Furthermore, many ski resorts have developed ski resort user agreements that comply with the legal requirements. In other words, in Japanese ski resorts, there are only Open ski runs where skiing is allowed and Closed areas where entry is prohibited. Moreover, in Japan, even accidents in close proximity to ski resorts that occur in closed areas are not referred to as “sidecountry” accidents, but rather as “mountain accidents,” and safety education and search-and-rescue activities are conducted accordingly. The data in this paper are in line with this classification.

In mountain recreation, the change in activities should be considered as a reason for the decrease in mountaineers fatalities. In the 1980s and 1990s, hard-core climbers, in which people climbed through deep snow on steep ridges, was popular among mountaineering groups. However, due to numerous accidents and other factors, the number of climbers in this group has been declining. Mountaineering groups are also affected by the aging of their members.

As for avalanche beacons, the domestically produced “Alpine Beacon 1500” was launched in Japan in 1993. This innovative model, the first in the world to incorporate LEDs and use lithium batteries, was developed through the tremendous efforts of amateur mountaineers who had lost friends in the mountains (this model is not currently on the market). In Japan, a backcountry boom began in the mid-1990s, mainly among snowboarding and freestyle skiing enthusiasts. Influenced by North American culture, the use of

avalanche beacons spread relatively smoothly in this demographic group. As a result of this boom, the number of beacon purchasers increased significantly, and by the 2000s, models from around the world were readily available at Japanese mountain equipment stores.

5. CONCLUSION

85% of avalanche fatalities in Japan occur in mountain areas, and 81% of the fatalities there are due to recreational activities.

Mountain recreation fatalities have seen a shift in demographics with a decrease in the percentage of mountaineers, who were once the primary group, and an increase in the percentage of skiers. Snowmobile accidents, which have been a problem in North America, are limited. The majority of the victims died of suffocation from being completely buried, although the depth of burial is often relatively shallow. Although avalanche beacons are becoming more widely used by skiers, the number of mountaineers who carry beacons still remains low.

Many avalanches that have resulted in fatalities in mountain recreation have been relatively small size. There are no distinct characteristics regarding the elevation of avalanche starting zones, but in terms of their terrain aspect, most accidents occur on the northeast to southeast slopes. Avalanches with sustained weak layers are mainly comprised of a combination of Melt-Freeze Crust and Faceted snow.

We speculate that demographics for mountain recreation fatalities will shift toward skiers in the near future. There is also strong concern about the increase in accidents involving foreign visitors to Japan which is already underway. We believe that more international cooperation among avalanche professionals is needed in the future.

REFERENCES

Izumi, K.: Japanese Avalanche Disaster Database, 2010, https://www.nhdr.niigata-u.ac.jp/nadare_db

Statham, G., P. Haegeli, E. Greene, K. Birkeland, C. Israelson, B. Tremper, C. Stethem, B. McMahon, B. White, and J. Kelly, 2018: A conceptual model of avalanche hazard, Natural Hazards, 90(2), 663-691.

CAA (2014) Observation guidelines and recording standards for weather, snowpack and avalanches. Canadian Avalanche Association, Revelstoke, BC